

How to integrate energy storage and demand response into the wide-area network control of the electric grid: Two specific technology examples

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(Energy Storage and Automated Demand Response)

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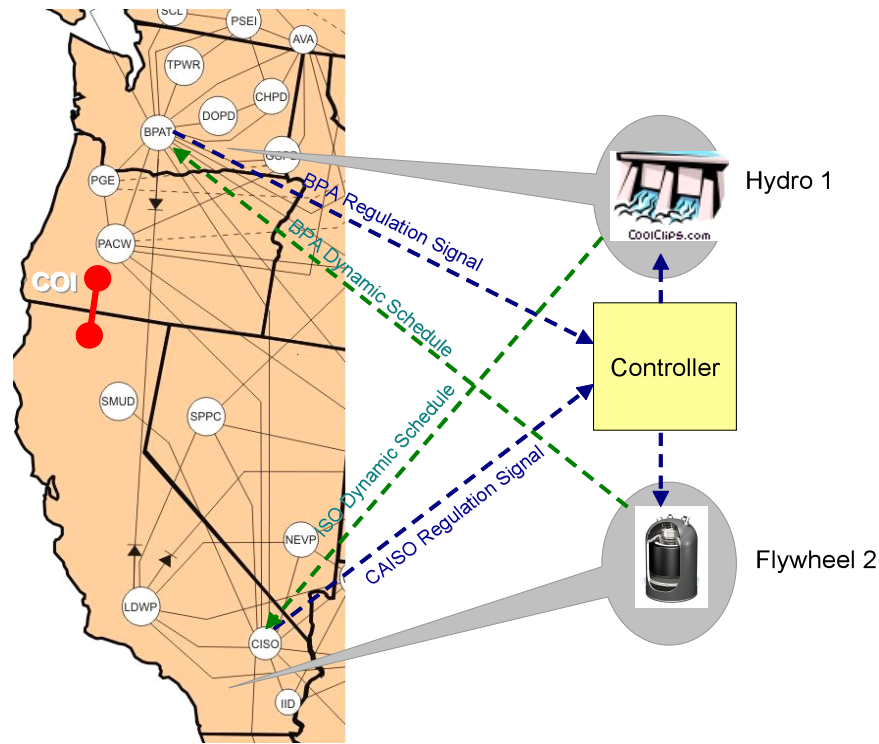


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Example #1: Wide-Area Energy Management Storage (WAEMS) Concept

A wide-area energy storage concept is proposed that provides a **centralized** control system that operates energy storage devices located in different places to provide energy and ancillary services that can be **shared** among balancing authorities.



Modeled Benefits of the WAEMS Concept

- ▶ Reduce regulation reserve by up to 30%
- ▶ Provide fast, cost-effective, and efficient ancillary services
 - Minimize wear-and-tear of conventional regulating units
 - Operate conventional regulating units close to their most efficient operating point
 - Allow the storage devices to excel in specific applications that fit their characteristics
 - Allow flywheel to follow fast regulation signals and hydroelectric to support the flywheel by maintaining a reasonable state-of-charge
- ▶ Easy scalable technology
- ▶ Compatibility:
 - Fully compatible with the existing BPA and CAISO AGC systems
 - Fully compatible with the other technologies such as ACE Diversity Interchange (ADI)
- ▶ Can be used with the other Balancing Authorities

Flywheel Field Tests

- ▶ **Objective:** To validate the ability of flywheels to meet the performance demands of the wide area energy management concept to support renewables integration
- ▶ Evaluated a 25-kWh, 100-kW flywheel



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Field Test Design

2009 April ACE and regulation data from BPA and CAISO

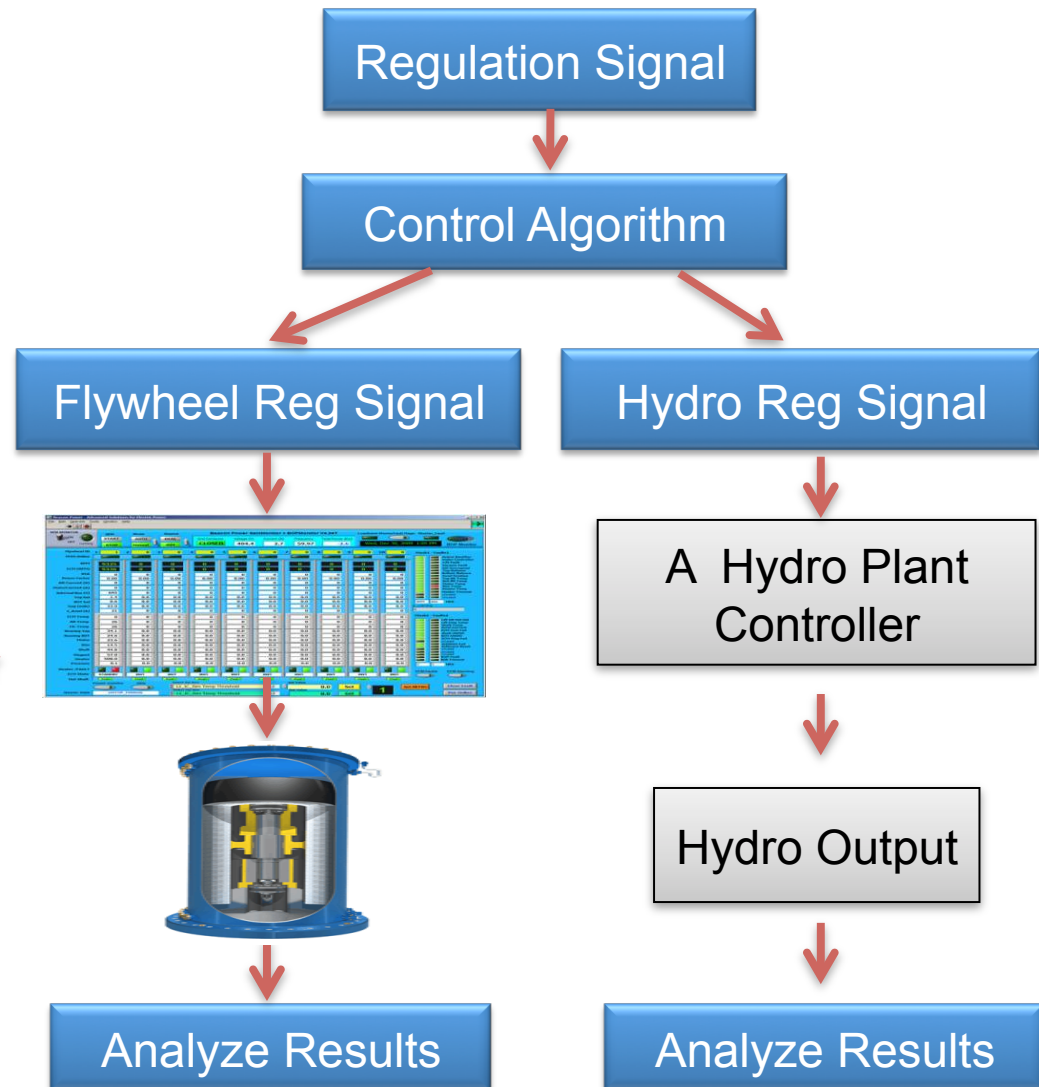
Implemented on
Beacon Flywheel
Controller

Field tests
conducted at the
Beacon Power
facility

Evaluation:

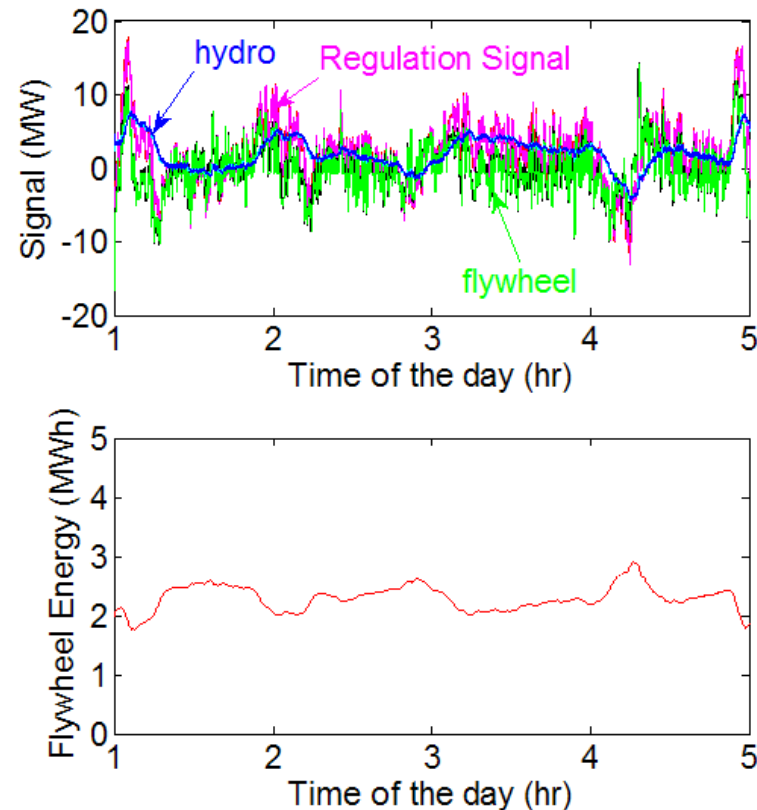
- Economic Analysis
- Performance Metrics

Beacon
Flywheel
Controller

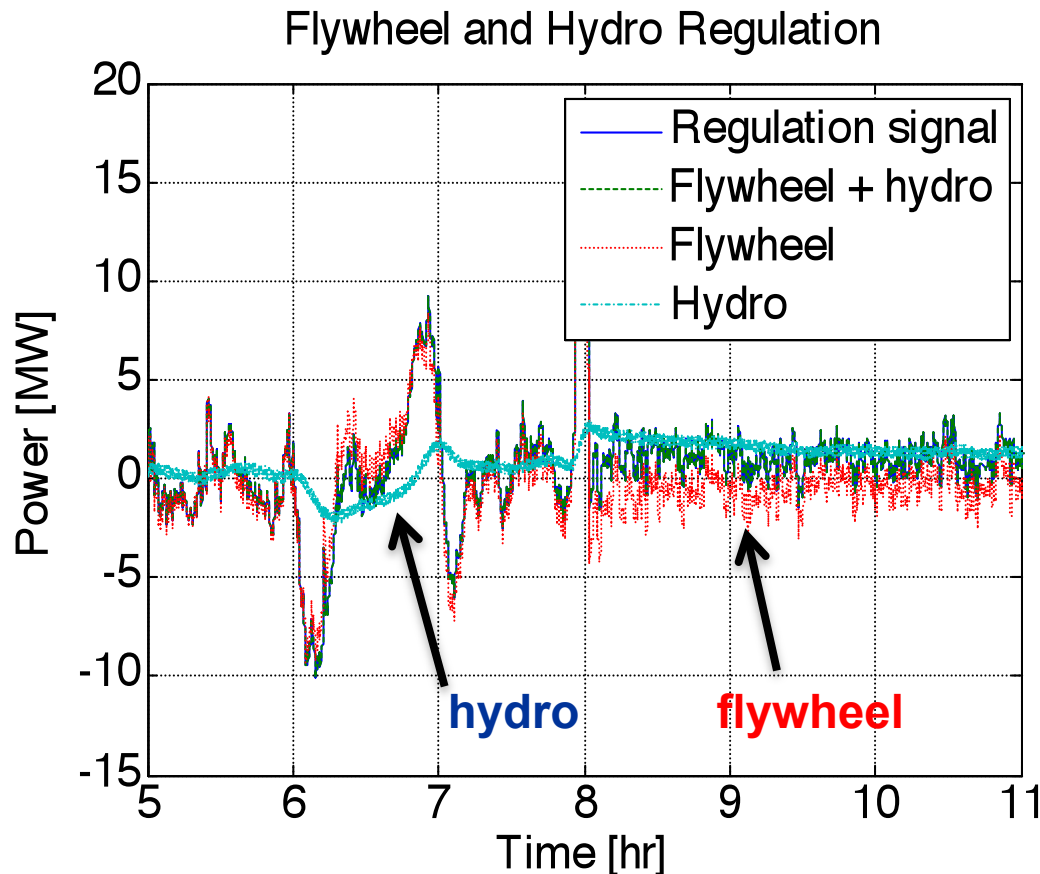


The Flywheel Field Test Results

- ▶ The flywheel followed regulation signal with minimal response delay
- ▶ The WAEMS algorithm successfully allocated the fast regulating signal to the flywheel and the slow one to the hydro
- ▶ The flywheel state-of-charge was maintained within its capacity limit by the support from the hydro unit



An Example Result: Flywheels+ Hydro plants



Calculated Breakeven Prices:

Pay-by-capacity

Flywheel-hydro: \$12.19/ \pm MW

Flywheel alone: \$20.37/ \pm MW

CAISO:

\$11.95/ \pm MW for regulation

BPA:

\$9.38/ \pm MW for regulation

If the same service was provided by the flywheel alone, because the regulation signal is biased, the flywheel will be out of energy in some hours and will not comply with the regulation requirement. This might double or triple the cost for the flywheel to provide the regulation service.

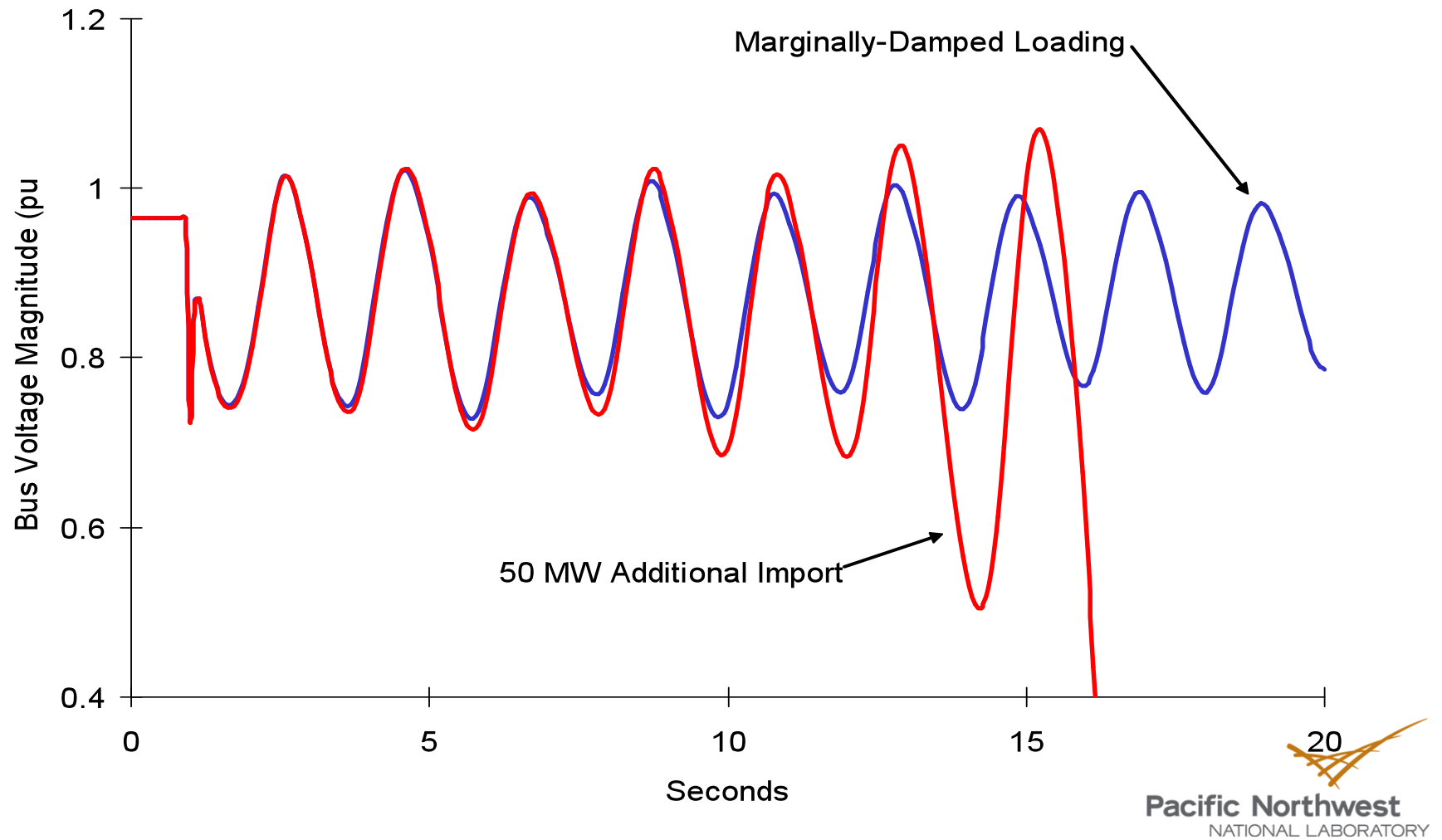
Conclusions – Flywheel Field Test

- ▶ Flywheel response delays are within seconds and state-of-charge is well maintained
- ▶ The WAEMS control algorithm successfully allocated the fast regulating signal to the flywheel and the slow one to the hydro
- ▶ The WAEMS combined service has
 - Fast response characteristic
 - No strict energy storage limitation
 - Better performance and more economical than flywheel-only service
- ▶ MW regulation service provided by a MW flywheel and MW hydro (assuming its cost is \$4 /MW) system will then cost **\$12.19 /MW** as compared to the average CAISO (**\$11.95/ MW**) and BPA (**\$9.38/ MW**) regulation price
- ▶ The WAEMS controller helped the hydro unit to reduce the wear and tear and allow it to operate close to the most preferred operating point

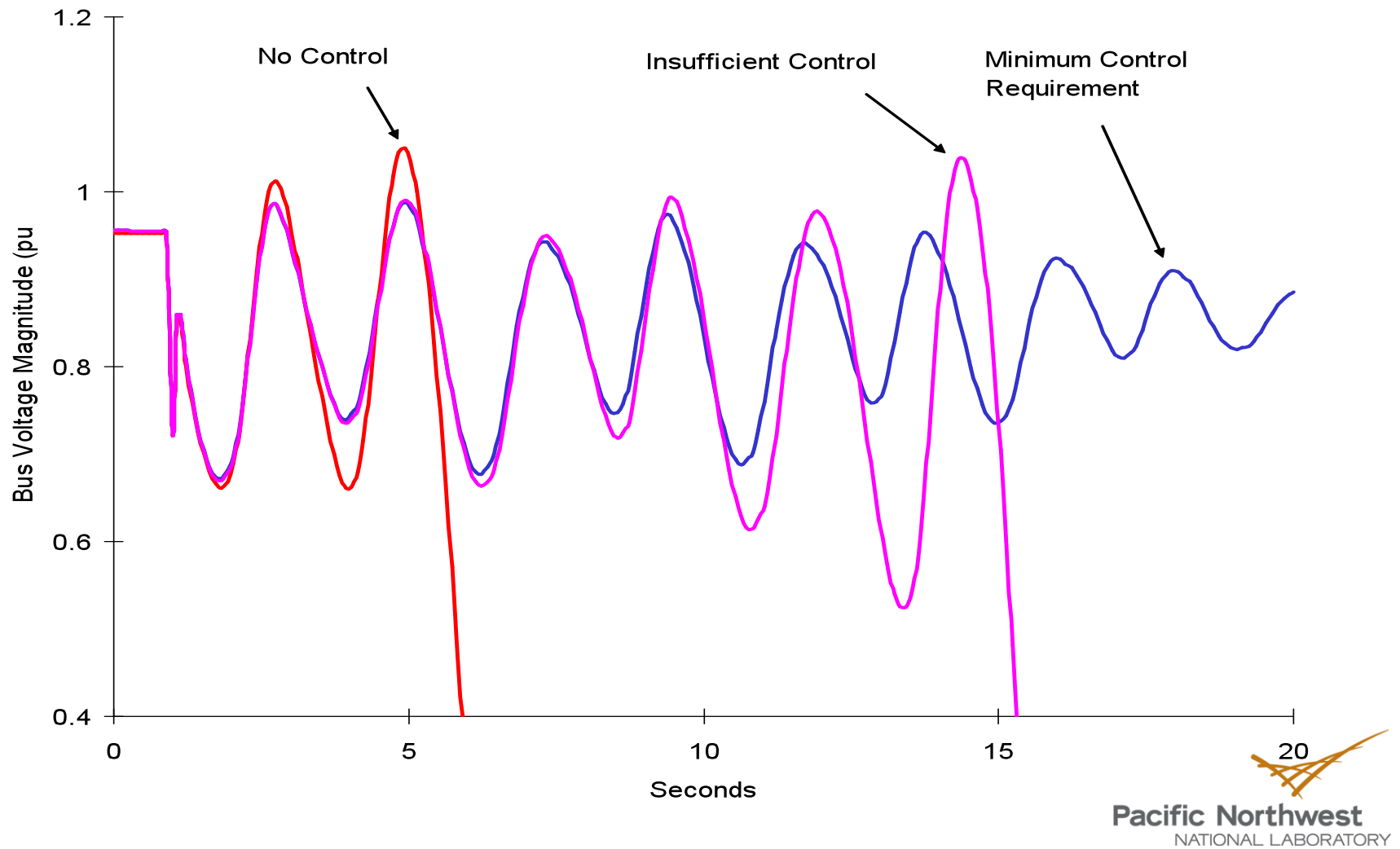
Example #2: Dynamic Load Control to Stabilize the Transmission Network

- ▶ Internally-funded research project in fiscal year 1996
- ▶ EPRI's Power System Analysis Package
 - Extended Transients / Mid-Term Stability Program (ETMSP)
 - Small Signal Stability Program (SSSP)
- ▶ WECC model (5000 bus)
 - 1999 heavy summer case
- ▶ Objective: Increase 'east of river' flow for stability-constrained import into Southern California
 - SCIT Nomogram
- ▶ Determine: Minimum control action for a given regional power import increase
 - dispersed control points
 - feedback modulation (compensation)
 - real- and/or reactive-power injection

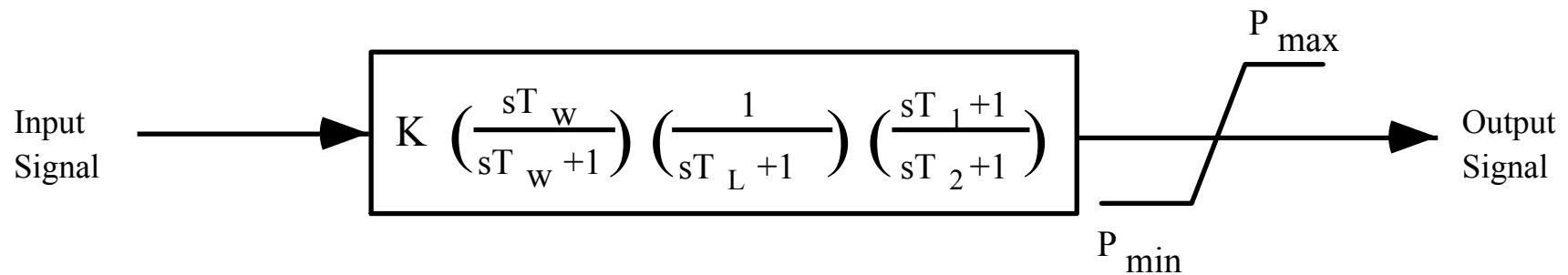
Marginally-Damped Loading



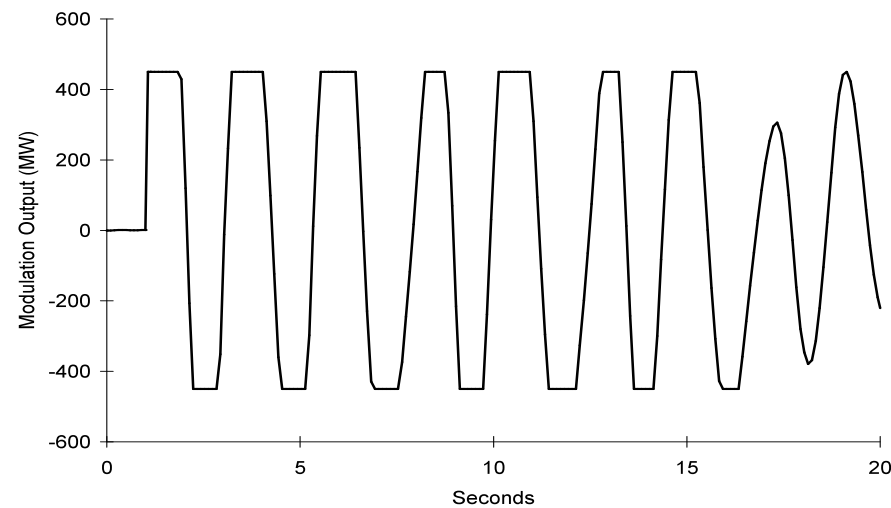
Imports Increased 400 MW



Modulation Control Block Diagram



Typical Modulation Output



Simulation Results – Single Location

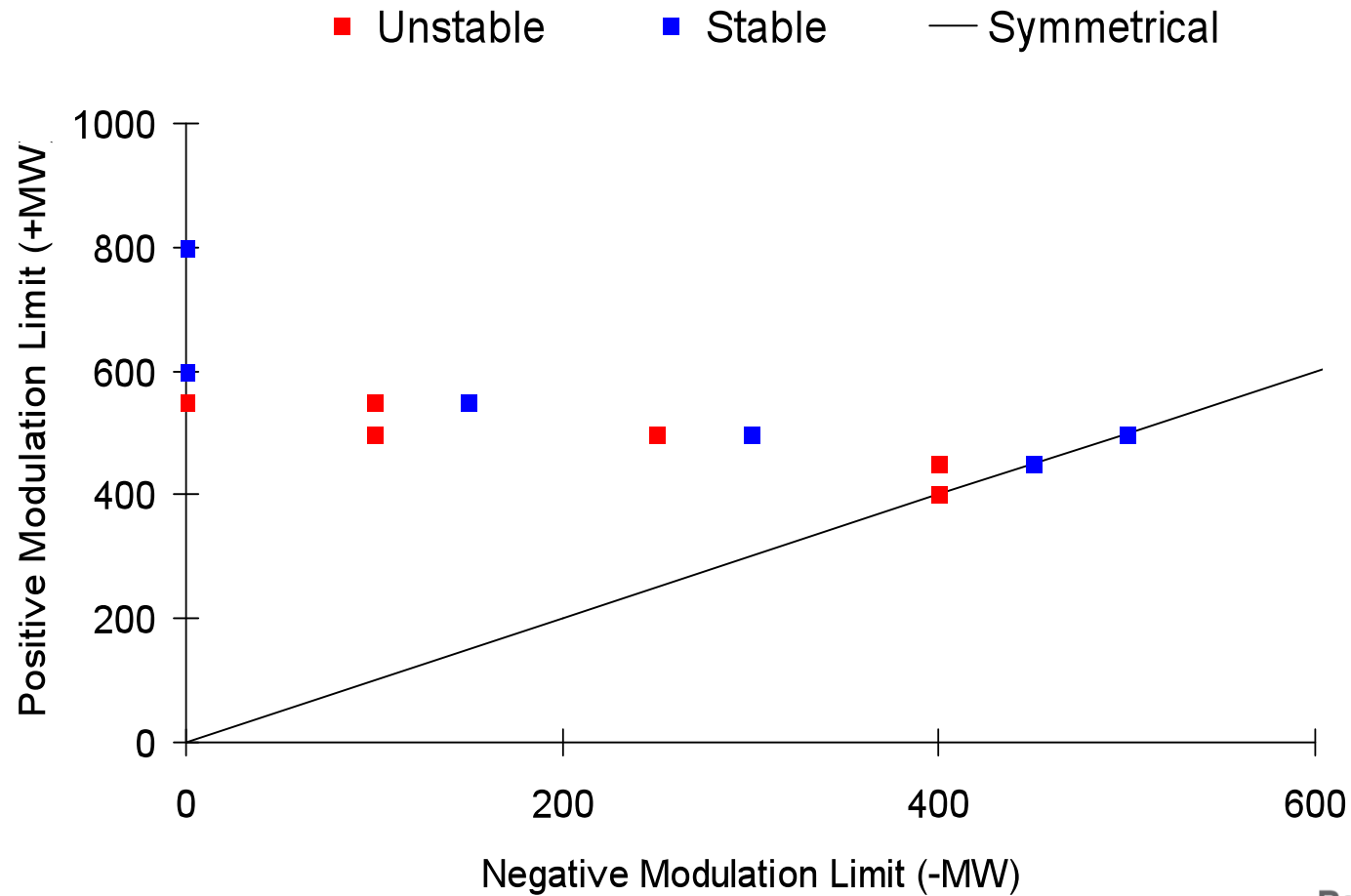
- ▶ Minimum modulation required at a single location necessary to provide 400-MW transmission enhancement
 - Real power modulation ± 450 MW
 - Reactive power modulation ± 500 MVAR



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Asymmetrical Modulation



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Study Results

- ▶ Dispersed control leverage
 - 1 actuator = 600 MW
 - 10 actuators = 44 MW ea. (440 MW total)
 - similar results with 100 actuators
- ▶ Modulation input signals
 - local voltage or frequency yielded similar results to a common input signal
 - frequency has inherent advantages (universality)
- ▶ Issue remains: How to implement?



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From then to now...

- ▶ Early conceptual framework for the *GridWise*™ initiative
 - Research now supported by the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability
 - Grid Friendly Appliance (GFA) technology being developed
 - GFA technology currently being field tested in conjunction with the Pacific Northwest GridWise™ Testbed Demonstration
 - Olympic Peninsula Demonstration
 - ◆ Demand reduction in response to market signals, part of Bonneville Power Administration's non-wires initiative
 - Grid Friendly Appliance Demonstration
 - ◆ Automatic underfrequency load shedding of certain interruptible appliances
- ▶ Additional research, development, and demonstration would be needed before this concept is ready for deployment to address grid operational issues